

the granulosa, nor, I think, is this possible without the aid of the microtome.

EXPLANATION OF PLATE II.

- Fig. 1.* Process of attachment of ovum attributed to *Gobius minutus*; the filaments are mostly curtailed. *fil*=filament; *p*=pedicle of attachment; *sp*=apertures in process of attachment; *z. r.*=zona radiata. (Zeiss D, Oc. 4.)
- Fig. 2* Group of ova *in situ*.  $\times 3$ .
- Fig. 3.* Detached ova highly magnified. *a. p.*=process of attachment; *e*=embryo; *y*=yolk.
- Figs. 4, 5.* Ova of *Gobius niger* from glycerine-preparations, enlarged under lens.
- Fig. 6.* Larval *Gobius* of 14th May, 1890; length 3.57 millim. *a. b.*=air-bladder; *h*=heart; *n*=notochord; *y*=yolk. Magnified.

IV.—Notes on *Radiolaria* from the Lower Palæozoic Rocks (Llandeilo-Caradoc) of the South of Scotland. By GEORGE JENNINGS HINDE, Ph.D.

[Plates III. & IV.]

THE Radiolaria described in this paper are contained in specimens of chert collected from several different localities in the Southern Uplands of Scotland, and sent to me for examination by the Geological Survey of Scotland through B. N. Peach, Esq., F.G.S. From the most promising pieces of this chert a number of microscopic sections have been prepared, and from these the forms have been studied. I may premise that the occurrence of these minute organisms in this chert was first announced by my friend Prof. H. Alleyne Nicholson, M.D.\*, of Aberdeen; but the specimens which he examined did not show the structure sufficiently well to allow of positive determination as to their real nature.

The chert containing the Radiolaria occurs in beds and intercalated nodular masses in a portion of the well-known series of Ordovician or Lower-Silurian strata forming the Southern Uplands of Scotland; and it is more particularly developed in the counties of Lanarkshire, Peeblesshire, and Edinburghshire. Mr. B. N. Peach †, who has lately been resurveying the district, informs me that he has traced a defi-

\* Trans. Edinb. Geol. Soc. vol. vi. pt. i. p. 56 (1890).

† A full description by Mr. Peach of the geological and stratigraphical relations of these rocks will appear in a forthcoming Geological Survey Memoir on Sheet 16.

nite zone of this Radiolarian chert over a considerable area. The zone is bounded below by a thin band of black shale containing Glenkiln graptolites of Llandeilo facies, and above it there is another mass of black shale with Lower Hartfell fossils, having a Caradoc facies. The zone included between these two beds of graptolitic shale consists, from below upwards, of nodular red and green cherts and red and green mudstones, followed by massive grey mudstones and cherts, mudstones and shales, succeeded above by black flints and shale, with a few Glenkiln graptolites. This Radiolarian zone of Mr. Peach thus corresponds with the Lower and part of the Middle Division of the Moffat Terrane of Prof. Lapworth (*Geol. Mag.* dec. iii. vol. vi. (1889) p. 66). Hitherto in this series of rocks the graptolitic zones have been chiefly studied and the intermediate beds of chert, regarded as unfossiliferous, have been neglected; but it is now certain that these latter are of organic origin equally as much as the former.

The Radiolarian chert is a very hard compact rock, with the usual hackly fracture; when unweathered it is for the most part of a steely-blue tint, but sometimes of a dull to a bright red; less frequently it has a greenish tint, and some pieces are even of a bright green. The rock is traversed in all directions by microscopic cracks and fissures, these latter now filled with crystalline quartz, and not unfrequently it is stained in irregular patches by a dark brown or blackish substance, which often follows the course of the microscopic cracks, so that they appear in sections like an intricate web of dark threads crossing a clear field. The mudstones accompanying the chert are greenish or reddish in tint and very fine-grained; in some cases they become siliceous and pass gradually into chert; in these transition-beds casts of Radiolaria are present in the rock.

In thin sections under the microscope the unstained portion of the chert is nearly transparent; it has a faint cloudy appearance, due to the presence of extremely minute irregularly-shaped mineral particles and small crystalline rods ranging from  $\cdot 002$  to  $\cdot 06$  millim. in length, with which it is filled. The nature of these minute particles cannot well be ascertained; but Mr. J. J. H. Teall, F.R.S., who has examined the sections, thinks that some may be flakes of mica, whilst the rods are suggestive of rutile. In polarized light, between crossed Nicols, this chert has a mottled appearance, more like that of flint than of ordinary chert.

Even with the aid of an ordinary hand-lens the fractured surface of the chert is seen to be filled with countless numbers

of the Radiolaria, which appear as minute, clear, circular specks; in thin sections of the unstained rock under the microscope they look like larger and smaller shadowy circles filled with a somewhat lighter material than the surrounding matrix; but in this condition no structure has been preserved. In sections of the red or jaspery chert the outlines of the Radiolaria are more clearly defined; the inner tests are occasionally shown as small red globes in the centres of larger, nearly transparent spheres, and not unfrequently the radiating spines are also indicated. In the red jaspery chert the enormous number of these organisms in the rock can be clearly seen, for the entire area of the section is occupied by their small circular outlines, which range from  $\cdot 01$  to  $\cdot 25$  millim. in diameter.

In the unstained and reddish chert just referred to the Radiolaria are only represented by casts, their tests having been dissolved or otherwise rendered undistinguishable; but where the chert has been stained by the darker substance mentioned above, which may be either due to carbon or iron, the tests themselves have been preserved in this material, which has replaced the original silica. In this condition the delicate lattice-like structure of many of them is now represented by a more or less dark meshwork, which, though as regards clearness of outline cannot be compared with the tests of recent or Tertiary fossil Radiolaria, is yet sufficient to show that the structure of these Palæozoic forms is essentially of the same character as that of their modern descendants. In these stained portions, which, as already noticed, occur as irregular patches in the generally transparent rock, fairly perfect specimens of Radiolaria showing one or more concentric spheres, and spines projecting from their surfaces, are intermingled with fragments of the meshwork, and entire and broken spines of other individuals, much in the same way as the entire forms and the fragmentary débris of these organisms occur in the unconsolidated Radiolarian earth from Barbados.

It is, however, often very difficult to ascertain with precision in the sections those particular features which form the basis of most of the family and generic characters in Hæckel's classification of these organisms. The tests are usually so filled with the dark staining material that they are either entirely opaque or present a blurred appearance. In these cases it is impracticable to determine definitely whether the structure was originally "lattice-like" or of an irregularly reticulate or "spongy" character, or whether an inner medullary test is present or not. The specimens available for study are limited to those shown in the sections of the chert, and

consequently very few in comparison with the numbers which may be obtained from a recent ooze or from loose fossil material.

With two or three doubtful exceptions the forms which I have been able to determine in this chert may be all included in one of the four legions or subclasses into which Hæckel has divided the Radiolaria, viz. that of the Spumellaria or Peripylea. Within this subclass but two suborders, the Beloidea and the Sphæroidea, are represented. In the first of these there is no connected siliceous test; but the skeleton consists of numerous solid siliceous spicules irregularly scattered in the soft structures surrounding the central capsule. Spicules of similar form and proportions to those of the existing members of this group, represented in plates ii. and iv. of Hæckel's 'Challenger' Report, are abundant in the chert. Some of them with three- or four-pointed rays (woodcut, *a-f*, p. 56) are very similar in form to the spicules of Calcsponges; others, however, with a central rod giving off divergent rays from its extremities (woodcut, *g*) are quite distinct from any known type of sponge-spicule. These detached spicules are in the same condition as the lattice-like Radiolaria with which they are intermingled, and there can be no doubt that like these latter they were originally siliceous. Though now detached from their normal positions, the inevitable result of the decay of the soft structures, yet instances are not unfrequent in this chert where several of these Beloid spicules occur in close proximity to each other, forming small groups, much in the same way as we should expect to be the case if forms like the recent *Lampoxanthium pandora*, Hæckel\*, and *Sphærozoum pandora*, H.†, were fossilized under favourable conditions.

The great majority of the Radiolaria in this chert, however, belong to the more normal types of the suborder Sphæroidea, in which the test consists of one or more rounded shells with a lattice-like or irregularly reticulate, so-called "spongy" structure. The simplest forms of these, in which the test is without spines or with only very minute secondary spines, are comparatively rare (Pl. III. figs. 1, 2). Tests in which there is a single large radial spine, with or without secondary spines, are abundant. In some the outer or cortical test consists of simple lattice-like structure with subcircular or irregular meshes (Pl. III. figs. 3, 4, 5, Pl. IV. fig. 3); in others the structure is "spongy" (Pl. III. fig. 7), whilst in another genus with the same structure there is a concentric inner or medullary test (Pl. III. figs. 8, 9). Shells with three or with

\* Chall. Report, pl. ii. fig. 1.

† *Ibid.* pl. iv. fig. 6.

four primary radial spines, some with, some without an inner or medullary test, are also common (Pl. III. fig. 6, Pl. IV. figs. 2, 4-7, 9-11); the structure of these appears to be uniformly of the irregularly reticulate or spongy character. The spines in some of these shells are of unusual length (Pl. IV. figs. 2, 9), but it is very rare to meet with specimens in which they all remain intact. There are also a few specimens with lattice tests and numerous smaller spines (Pl. IV. fig. 1) included in the well-known recent genus *Acanthosphæra*, Ehrenberg, and others with larger spines (Pl. III. fig. 11, Pl. IV. fig. 8) which I have referred to *Haliomma*.

In addition to the above, mention may be made of some peculiar spicules (woodcut, p. 56, *i, k, l*) of the same general characters as the Beloid forms already referred to, which seem to correspond to the spicular skeletons of some existing Radiolaria, which are regarded by Hæckel as the simplest and most primitive types of the great primary division of the Nassellaria, in which they form the distinct suborder Plectoidea\*. The spicules in question consist of a variable number of simple or branched arms or rays proceeding from a centre; the rays may be either free or connected by irregular fibres with each other. Spicules of this type are rare and not often entire, and their true position is not altogether free from doubt.

These Palæozoic Radiolaria, so far as can be judged from their present condition, do not differ in any striking respect from the existing forms of the group or from those numerous fossil ones which have been lately described by Dr. Rüst† and others from Jurassic and Cretaceous strata. Some of the more peculiar forms with one or with three primary radial spines bear a close resemblance to specimens figured by v. Dunikowski‡ from the Lower Liassic strata of Schafberg, in the Tyrol. The detached spicules of the Beloidea have likewise been noticed by Rüst in the Radiolarian Jurassic strata of the continent. The quantity of this ancient chert which has as yet been examined is too small to permit of any general deductions as to the characters of the Radiolaria contained in it; but it is noticeable that so far, if we except the few spicules doubtfully referred to the Nassellarian Plectoidea, the forms belong to only two divisions of the Spumellaria, the Beloidea and the Sphæroidea; and there is an apparent absence not only of the discoidal and elliptical forms of the

\* Chall. Report, pt. ii. p. 899, pl. xci.

† 'Palæontographica,' Bd. xxxi. (1885), Bd. xxxiv. (1888).

‡ Denkschr. d. k. Akad. d. Wiss. Wien, Bd. xlv. (1882), pp. 187, 188, Taf. v. figs. 53-55, 59.

other suborders of this legion, but also of the important Nassellarian Cystellaria, which are extremely abundant both in recent deposits and in all Tertiary and Mesozoic Radiolarian beds which have as yet been examined.

With the exception of the Radiolaria very few other organisms can be recognized in the sections of this chert-rock. There are one or two spicules of Hexactinellid sponges, readily distinguishable from the detached Beloid spicules by their larger size and distinctive forms, and I have met with a few minute toothed plates and detached denticles, which bear a certain resemblance to the radulæ of naked Molluscs; there are further numerous almond-shaped hollow bodies about .1 millim. in length, with imperforate siliceous walls, of whose nature I am quite ignorant. This Ordovician chert may therefore be fairly considered to be due to the accumulation of the tests of Radiolaria, and is thus a *pure* Radiolarian rock, equally as much as the Tertiary beds of Barbados and the Nicobar Islands, which, according to Hæckel, correspond to the recent Radiolarian ooze, "and are certainly of deep-sea origin, having probably been deposited at depths greater than 2000 fathoms"\*. If the same conclusion is applicable to this fossil chert, it represents, as Prof. H. A. Nicholson † has already pointed out, a true deep-sea deposit in the Palæozoic period, the existence of which in the geological series has of late been disputed. The beds of fine-grained red and green mudstones associated with this chert likewise favour the same view of its origin in deep water.

Hitherto only a single species of Radiolaria has been described from the entire Palæozoic series, and this was discovered by Dr. Rothpletz ‡ in siliceous shale of Upper Silurian age at Langenstriefis, in Saxony. This Radiolarian shale, like the Scotch chert, is accompanied by beds with graptolites. It is only since 1876 that Radiolaria were known in any rocks older than Tertiary by the discovery by v. Zittel § of a few forms in the Upper Chalk of Germany; since then the existence of an abundant and varied Radiolarian fauna in beds of chert and jasper of Lower Cretaceous and Jurassic age has been proved by Dr. Rüst ||, and v. Dunikowski ¶ has described numerous species in the Lower Lias of the Tyrol.

\* Chall. Report, vol. xviii. pt. i. p. clxix.

† Trans. Edinb. Geol. Soc. vol. vi. pt. i. p. 56.

‡ Zeitschr. d. deutsch. geol. Gesellsch. Bd. xxxii. (1880) p. 447, pl. xxi.

§ *Ibid.* Bd. xxviii. (1876) pp. 75-86, pl. ii.

|| 'Palæontographica,' Bd. xxxi., xxxiv.

¶ *Op. cit.*

Lately Dr. Rüst \* has announced the occurrence of *Radiolaria* in all the principal divisions of the Palæozoic series, but a detailed description of the forms has not yet appeared.

Very few *Radiolaria* have been as yet noticed from the rocks of this country. Mr. W. H. Shrubsole † has recorded three or four species from the London Clay of Sheppey; Dr. Rüst has discovered two species in the flints of the Upper Chalk ‡ and a few remains in coprolites from the Lias of Gloucester §; and Prof. Sollas ||, many years since, noted their occurrence in the Cambridge Greensand, but he has not yet described the species. The presence of *Radiolaria* in the Coal-measures of Lancashire ¶ and in the Carboniferous Limestone of North Wales \*\* has been reported from time to time; but the minute spherical bodies in the Coal-measures known as *Traquairia* have been shown by Prof. W. C. Williamson †† to be vegetable structures, and the same author considers that the objects in the Carboniferous Limestones, presumed to be *Radiolaria*, are really composed of carbonate of lime, and he has named them *Calcisphaera* ††. I have examined microscopic sections of limestones containing these organisms, and I agree with Prof. Williamson that there is no evidence to support the view that they were originally siliceous.

The apparent rarity of *Radiolaria* in the later Palæozoic and more recent strata in this country renders their occurrence in such great abundance in this Ordovician chert still more remarkable. Considerable attention has been paid lately to the nature of the chert and allied siliceous rocks of the different British sedimentary formations, but hitherto no other siliceous organisms than sponges have been found in them; and this Scotch chert is the first instance in which in our area this description of rock has been traced to the skeletons of other organisms than sponges. A large series of sections of chert from different formations has come under my own notice of late years, but in only one instance, that of a chert-bed in the Carboniferous Limestone of Flintshire, have I met with *Radiolaria*, and in this there were only a few individuals of a

\* Jahresh. d. naturhistor. Gesellsch. zu Hannover, 1883-87 (1888), pp. 49-56.

† Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 121.

‡ 'Palæontographica,' Bd. xxxiv. p. 185.

§ *Ibid.* Bd. xxxi. p. 278.

|| Quart. Journ. Geol. Soc. vol. xxix. 1873, p. 78.

¶ Brit. Assoc. Report, Brighton, 1872, p. 126.

\*\* 'Nature,' March 1877, p. 461; Ann. Rep. Chester Soc. Nat. Hist. 1876-77, p. 10.

†† Phil. Trans. vol. clxxi. (1880) pt. ii. p. 511.

‡‡ *Ibid.* p. 520, pl. xx. figs. 67-81.

single species. The preservation of the Radiolaria in this Ordovician chert, which has evidently been subjected to considerable disturbance, is an indication that if these organisms had entered largely into the composition of other beds of chert in this country they would probably ere now have been recognized in them. The observations of Dr. Rüst\* have led him to conclude that on the continent in the majority of cases chert and other siliceous rocks may be attributed to Radiolaria; but in this country, according to present experience, similar rocks are mainly derived from the remains of siliceous sponges and very exceptionally from those of Radiolaria.

#### *Description of Species.*

In attempting to classify these ancient Radiolaria I have followed as far as possible the latest system of Prof. Hæckel, contained in the 'Challenger' Report on this group. In this elaborate work the limits assigned to genera are extremely narrow and precise, and it is no wonder therefore that even with the greatest desire for comprehension it should be found impracticable to fit all these fossils into the divisions, numerous though they are, which have been already established, and I have therefore reluctantly been obliged to propose additional genera to include some of them.

Class *RADIOLARIA*, Müller.

Subclass *SPUMELLARIA*, Ehrenberg.

Order *SPHÆRELLARIA*, Hæckel.

Suborder *SPHÆROIDEA*, Hæckel.

Family *Liosphærida*, Hæckel.

Sphæroidea without radial spines on the surface of the spherical shell; living solitary (not associated in colonies). ('Challenger' Report, part i. p. 59.)

Genus *STYPTOSPLÆRA*, Hæckel.

Liosphærida forming a solid sphere of spongy framework, without enclosed medullary shell and without central cavity. (Chall. Rep. part i. p. 86.)

*Styptosphæra antiqua*, sp. n. (Pl. III. fig. 1.)

The irregularly reticulate or spongy framework appears to

\* Jahresb. d. naturhist. Gesellsch. zu Hannover, 1883-87 (1888), p. 56.



be of an equally close character throughout the test, the interspaces are very minute, showing sometimes as minute circular pores about  $\cdot 005$  millim. in diameter, sometimes as sinuous apertures. Surface usually smooth and even, occasionally with minute spines. Diameter of test ranging from  $\cdot 15$  to  $\cdot 24$  millim.

*Distribution* \*. Abington, Lanarkshire; Broughton, Hartree Hill, Peeblesshire.

#### Genus SPONGOPLEGMA, Hæckel.

Liosphærida forming a sphere of spongy framework, which encloses in the centre one single latticed medullary shell. (Chall. Rep. part i. p. 89.)

#### *Spongoplegma priscum*, sp. n. (Pl. III. fig. 2.)

The surface of the cortical shell relatively smooth, with apparently regular apertures, the reticulate or spongy framework between the cortical and the medullary shell with circular or irregular apertures about  $\cdot 01$  millim. wide; the medullary shell well marked by its closer and denser structure. The specimen figured is shown in section. Diameter of cortical shell  $\cdot 15$  to  $\cdot 2$  millim., thickness of shell  $\cdot 012$  millim.; width of medullary shell  $\cdot 075$  millim.

*Distribution*.—Hartree Hill, Kilbucho, and Broughton Heights, near Broughton, Peeblesshire.

#### Genus DIPLOPLEGMA, gen. nov.†

Liosphærida with a relatively large inner (cortical?) test of irregularly reticulate or spongy framework and an outer shell of the same structure, the two connected by radial bars. In this genus the inner test is sufficiently large to be regarded as an inner cortical shell, and in this respect it resembles *Liosphæra*, Hæckel ('Challenger' Report, pt. i. p. 76), which has two cortical shells. It differs from *Liosphæra*, however, in the irregularly reticulate or spongy nature of the tests.

#### *Diploplegma cinctum*, sp. n. (Pl. III. fig. 10.)

Surface of outer test uneven, but without definite spines. The inner test connected by numerous short radial bars with

\* As all the specimens are from the same geological horizon (Llandeilo-Caradoc) referred to in the previous part of the paper, it is not necessary to indicate it in connexion with each species.

† διπλός, double, πλέγμα, network.

the outer, so that in section the outer sphere has the appearance of an encircling ring. The framework of both outer and inner spheres apparently similar. No central medullary shell can be recognized. The minute structure of the meshwork is obscured by the dark infilling. Diameter of outer sphere  $\cdot 25$ , of the inner  $\cdot 15$ ; length of radial beams  $\cdot 015$  millim. Rare.

*Distribution.* Abington, Lanarkshire; Hartree Hill, Peeblesshire.

#### Family *Staurosphærida*, Hæckel.

Sphæroidea with four radial spines on the surface of the spherical shell, forming a regular cross, being opposite in pairs in two axes perpendicular to one another. (Chall. Rep. pt. i. p. 151.)

#### Genus *STAURODORAS*, Hæckel.

*Staurosphærida* with spongy spherical shell and four crossed simple spines. (Chall. Rep. pt. i. p. 163.)

#### *Staurodoras gracilis*, sp. n. (Pl. IV. fig. 7.)

The siliceous mesh apparently of a close irregular character, with apertures of about  $\cdot 01$  millim. wide. The radial spines slender, evenly tapering, about two thirds as long as the diameter of the shell. In the specimen figured one of the spines has been broken off. Diameter of the sphere  $\cdot 11$ ; length of spines  $0\cdot 7$ , thickness at base  $\cdot 01$  millim. Another specimen has the spines stouter, measuring  $\cdot 02$  millim. at the base.

Three species of this genus have been described by Duniowski\* from the Lower Lias of Schafberg, near Salzburg; but in these the siliceous framework appears to be more regular and the spines stouter than in the present species.

*Distribution.* Abington, Lanarkshire; Hartree Hill, Peeblesshire.

#### Genus *STAUROPLEGMA*, gen. nov.

*Staurosphærida* with solid, irregularly reticulate or spongy shell, a concentric medullary shell, and four simple spines approximately in the form of a cross. This genus differs from *Staurodoras* by the possession of an inner medullary test.

\* Denkschr. d. k. Akad. d. Wiss. Wien, Bd. xlv. p. 183, pl. v. figs. 56, 57, 58.

*Stauroplegma brevispina*, sp. n. (Pl. IV. fig. 5.)

Surface of cortical shell smooth, the outer wall distinct from the interior meshwork, the medullary test now shown by its darker structure. Radial spines conical, shorter than the radius of the test. Diameter of shell  $\cdot 16$  millim., of medullary test  $\cdot 06$ ; length of spines  $\cdot 04$ , basal thickness  $\cdot 017$ .

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

*Stauroplegma compressum*, sp. n. (Pl. IV. fig. 6.)

Test slightly elliptical, in part perhaps due to compression; surface uneven, with here and there circular pores  $\cdot 015$  millim. wide. The spines tapering, about two thirds as long as the diameter of the test, apparently unequal in length; they can be traced to the surface of the inner shell. Diameter of test  $\cdot 16$ , of inner shell  $\cdot 06$ ; length of spines  $\cdot 09$  to  $\cdot 12$ , width at base  $\cdot 013$  millim. In the specimen figured one spine has been broken off. Rare.

*Distribution.* Near Moorfoots, Edinburghshire.

*Stauroplegma barbatum*, sp. n. (Pl. III. fig. 6.)

Surface of cortical test rough, as if with minute spines. The medullary test indicated in the specimen figured by a partially clear subcentral space. Spines longer than the diameter of the sphere; they are not strictly in the form of a cross, but their present position may in part arise from subsequent misplacement. Diameter of sphere  $\cdot 135$ ; length of spines  $\cdot 18$ , thickness at base  $\cdot 02$  millim. Rare.

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

*Stauroplegma diffusum*, sp. n. (Pl. IV. fig. 4.)

Surface of cortical test irregular and uneven; an inner medullary shell is shown by a ring of darker structure, and within this is a central lighter space, which may perhaps indicate the presence of a second medullary test. The radial spines are shorter than the radius of the sphere, measuring from the surface. Diameter of sphere  $\cdot 13$ , of outer medullary test  $\cdot 07$ , of inner test (?)  $\cdot 03$  millim.; length of spines  $\cdot 04$ , thickness at base  $\cdot 012$  millim.

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

Family **Astrosphærida**, Hæckel.

Sphæroidea with numerous (8 to 12 or more, commonly

between 20 and 60) radial spines on the surface of the spherical shell; living solitary. (Chall. Rep. pt. i. p. 206.)

Genus ACANTHOSPHÆRA, Ehrenberg.

Astrosphærida with one simple lattice sphere, covered with simple radial spines of the same kind. (Hæckel, Chall. Rep. pt. i. p. 209.)

*Acanthosphæra antiqua*, sp. n. (Pl. IV. fig. 1.)

Shell thin-walled, pores subcircular and wider than the inclosing framework. Spines short, conical, apparently numerous, though, owing to the way in which the specimen figured has been infilled with dark staining material, only those near the outer margin can be clearly seen. The missing part of the specimen figured has been cut off by a quartz-vein. Diameter of test  $\cdot 16$ , of the pores  $\cdot 015$  to  $\cdot 02$ ; length of spines  $\cdot 02$ , thickness at base  $\cdot 01$  millim. Rare.

*Distribution.* Hartree Hill, Kilbucho.

Genus HALIOMMA, Ehrenberg (in part).

Astrosphærida with one medullary (intracapsular) and one cortical (extracapsular) shell, which are connected by radial beams piercing the central capsule. Shell-surface covered with simple radial spines of the same kind. (Hæckel, Chall. Rep. pt. i. p. 220.)

*Haliomma vetustum*, sp. n. (Pl. III. fig. 11.)

Cortical test moderately thick, with small circular pores and relatively robust, short, conical spines, of which there are nine on the surface exposed. The specimen figured is partly a section; there are no traces of radial beams connecting the inner with the outer test; their apparent absence may be due to the fossilization. Diameter of sphere  $\cdot 22$ , of the inner test  $\cdot 08$ , pores  $\cdot 013$ ; length of spines  $\cdot 06$ , thickness at base  $\cdot 02$  millim.

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

*Haliomma cornutum*, sp. n. (Pl. IV. fig. 8.)

In the specimen figured the characters of the cortical test are obscured by the dark infilling, and the inner test is only indicated by a lighter area. There are at least seven equal, slender, tapering spines nearly as long as the diameter of the

test. Diameter of sphere  $\cdot 09$ , of inner test  $\cdot 03$ ; length of spines  $\cdot 075$ , basal thickness  $\cdot 01$  millim.

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

The genera described below, though embraced in the same suborder—Sphæroidea—as the preceding forms, do not find a place in any of the families of this group, as described by Hæckel in the ‘Challenger’ Report. They may possibly represent new families; but as their condition of preservation and mode of occurrence are very unfavourable for a thorough determination of their structural characters, I do not propose to define their position in Hæckel’s system, but shall limit myself to giving generic and specific descriptions, so far as these can be ascertained.

#### Genus DORYSPHÆRA \*, gen. nov.

Sphæroidea with simple spherical lattice-shells and a single radial spine extending from the surface of the test. No medullary test.

Fossil forms of this genus have been already figured by v. Dunikowski from the Liassic strata of Schafberg, but no name was given to them, possibly under the idea that they were imperfect specimens of forms with normally two or four radial spines. In this Ordovician chert, however, specimens with but a single radial spine are not at all uncommon, and they may be regarded as being in their original condition. The genus *Lithapium* †, Hæckel, has a simple lattice-shell, with only a single radial spine; but it is ellipsoidal or pear-shaped, and thus is included in a different suborder.

#### *Dorysphæra reticulata*, sp. n. (Pl. III. fig. 3, Pl. IV. fig. 3.)

The framework of the shell thin, of an open, subpolygonal, reticulate character, the meshes unequal in size, subcircular to subpolygonal. Radial spine short, styliform. Diameter of sphere  $\cdot 18$ , meshes from  $\cdot 005$  to  $\cdot 015$  millim., thickness of framework about  $\cdot 005$  millim. Radial spine (probably imperfect)  $\cdot 07$ , breadth of base  $\cdot 01$  to  $\cdot 02$  millim.

*Distribution.* Abington, Lanarkshire; Broughton Heights, Peeblesshire.

\* δόρυ, a spear, σφαῖρα, sphere.

† ‘Challenger’ Rep. pt. i. p. 303.

*Dorysphaera nucula*, sp. n. (Pl. III. fig. 5.)

The shell smaller and the framework thicker than in the preceding form. Pores subcircular. Radial spine short, styliform. Diameter of shell  $\cdot 13$ , pores  $\cdot 01$ , intermediate spaces about  $\cdot 007$ ; spine  $\cdot 03$ , thickness at base  $\cdot 02$  millim. Rare.

*Distribution.* Hartree Hill, Kilbucho, Peeblesshire.

*Dorysphaera laxa*, sp. n. (Pl. III. fig. 4.)

Framework of test thin, reticulate, the meshes subcircular, unequal, relatively large. Spine short, in the specimen figured it is seen projecting obliquely. Diameter of shell  $\cdot 12$ , mesh-apertures from  $\cdot 01$  to  $\cdot 025$  millim. in width, intermediate framework about  $\cdot 007$ , thickness of base of spine  $\cdot 015$  millim. This form differs from *D. reticulata* principally in the distinctly larger size of the mesh-apertures.

*Distribution.* Abington, Lanarkshire; Hartree Hill, Peeblesshire.

## Genus DORYPLEGMA\*, gen. nov.

Sphæroidea with cortical shells of irregularly reticulate or spongy framework, inclosing a central medullary shell and with a single primary radial spine. Secondary or smaller spines occasionally present. The structure of the shell in this genus is the same as in *Spongoplegma*, Hæckel, but with the addition of a radial spine and sometimes of secondary spines. From *Dorysphaera* it is distinguished by the different character of the framework and the presence of a medullary shell.

*Doryplegma nasutum*, sp. n. (Pl. III. fig. 9.)

The wall of the sphere well marked and distinct from the reticulate structure of the space within. Radial spine conical, tapering, shorter than the diameter of the sphere; secondary spines small, acute, in some specimens none can be distinguished. The lower portion of the specimen figured has been displaced by a quartz-vein, and the interior structure is only partially shown. Diameter of sphere  $\cdot 2$ , of medullary test  $\cdot 08$ , thickness of cortical shell  $\cdot 017$ ; length of radial spine  $\cdot 11$ , thickness at base  $\cdot 02$ ; length of secondary spines  $\cdot 015$  millim. Specimens not infrequent.

*Distribution.* Hartree Hill; Broughton Heights, Peeblesshire.

\* δόρυ, a spear, πλέγμα, network.

*Doryplegma gracile*, sp. n. (Pl. III. fig. 8.)

The reticulate or spongy framework close, with small irregular apertures. Spine conical, tapering, about as long as the diameter of the shell. Smaller than the preceding form and with longer spine. Diameter of cortical shell  $\cdot 13$ , of medullary test  $\cdot 05$ ; length of radial spine  $\cdot 15$ , basal thickness  $\cdot 015$  millim.

*Distribution.* Hartree Hill, Peeblesshire.

## Genus DORYDICTYUM \*, gen. nov.

Sphæroidea with tests of irregularly reticulate or spongy framework and a simple radial spine, with or without secondary spines. The structure of the test corresponds with that of *Styptosphaera*, Hæckel, and it differs from this genus by the addition of a radial spine. It is distinguished from *Doryplegma* by the absence of a medullary test.

*Dorydictyum simplex*, sp. n. (Pl. III. fig. 7.)

The reticulate framework of the same character throughout, with very minute pores. Radial spine robust, styliiform, nearly as long as the diameter of the shell. Occasional minute secondary spines. Diameter of the test  $\cdot 15$ ; length of radial spine  $\cdot 12$ , basal thickness  $\cdot 022$  millim. Rare.

*Distribution.* Broughton Heights, Broughton, Peeblesshire.

## Genus TRIPOSPHÆRA †, gen. nov.

Sphæroidea with an irregularly reticulate or spongy framework, a medullary shell, and three primary radial spines. Smaller secondary spines occasionally present.

Forms with spherical shells and three prominent radial spines, but without a medullary shell, have been described by Dunikowski‡ from the Liassic strata of Schafberg, and placed by him in the genus *Spongechinus*, Hæckel; but in the 'Challenger' Report§ one of them is regarded as discoidal and referred to the genus *Spongotripus*, H. Dr. Rüst has also described rounded *latticed* forms with three prominent spines from Jurassic and Cretaceous strata; they were originally placed in the new genus *Triactoma* (Palæontogr.

\* δόρυ, a spear, δίκτυον, network.

† τρίπους, a tripod, σφαῖρα, sphere.

‡ Denkschr. d. k. Akad. der Wiss. Wien, Bd. xlv. p. 188, pl. v. figs. 54, 59.

§ Pt. i. p. 581.

Bd. xxxi. p. 289), but in a subsequent memoir they are considered as Discoidea under the modified name *Triactis* (Palæontogr. Bd. xxxiv. p. 197). Hæckel\* has referred other discoidal three-spined forms to the genus *Triactiscus*. So far as I can ascertain no spherical "spongy" forms with a medullary shell and three radial spines, as in the proposed genus, have as yet been described. It is difficult to ascertain with absolute certainty now that these minute shells are imbedded in the solid chert whether particular specimens are discoidal or spherical; but their outlines are uniformly circular, and if discoidal shells had been present one would have expected to meet with lenticular or elliptical forms in the rock-sections.

*Triposphæra Peachii*, sp. n. (Pl. IV. fig. 9.)

Shell approximately spherical, the reticulate framework close. The radial spines nearly twice as long as the diameter of the test, straight or curved, tapering gradually, inequidistant from each other. In no specimen are all the spines intact, but they appear to have been equal in length originally. The medullary test is not shown in the specimen figured owing to the dark infilling, but it is present in others. Diameter of shell .18, of medullary test .05; length of spines .42, basal thickness .02 millim. This species is named after B. N. Peach, Esq., F.G.S., of the Geological Survey of Scotland, to whom I am indebted for the opportunity of studying these fossils.

*Distribution.* Abington, Lanarkshire; Broughton Heights, Peeblesshire.

*Triposphæra hastata*, sp. n. (Pl. IV. fig. 2.)

Shell of close framework, with minute pores; surface uneven and rough, as if with minute blunt spines. The medullary test in the specimen figured is indicated by a light central space. Spines straight, robust, nearly twice as long as the diameter of the sphere, inequidistant from each other. Only one is preserved intact in the specimen figured, the other two are indicated by their stumpy bases. Diameter of sphere .27, of the medullary test .055; length of spines .5, basal thickness .025 millim.

*Distribution.* Near Abington, Lanarkshire.

*Triposphæra densa*, sp. n. (Pl. IV. fig. 10.)

Surface of shell nearly even, the three radial spines slender,

\* Chall. Rep. pt. i. p. 432.



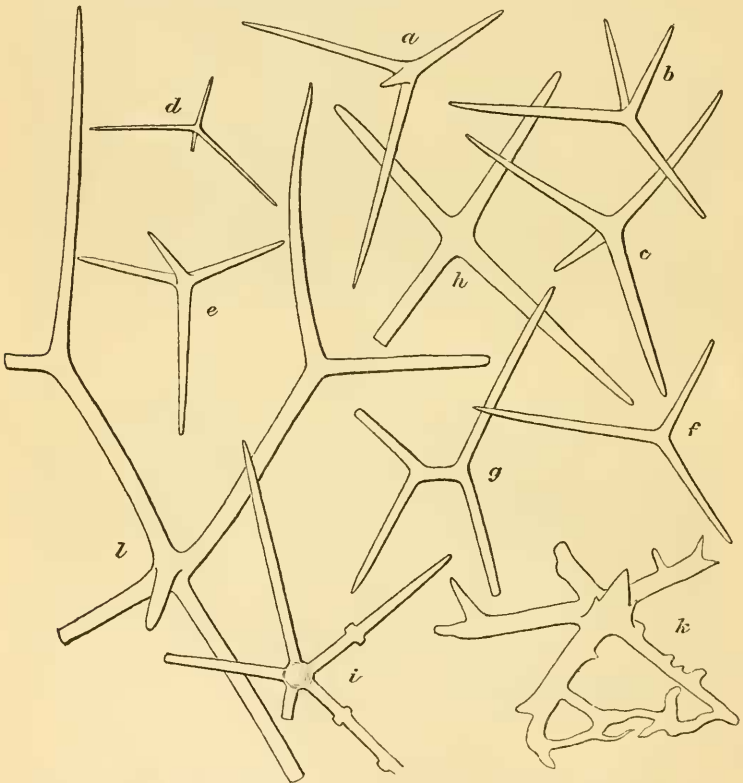
conical, nearly as long as the radius of the shell; they are inequidistant and do not seem to be all in the same plane. The specimen is so infiltrated with dark material that the medullary shell cannot be distinguished. Diameter of test  $\cdot 18$ ; length of spines  $\cdot 06$ , basal thickness  $\cdot 015$  millim.

*Distribution.* Broughton Heights, Peeblesshire.

*Triposphæra armata*, sp. n. (Pl. IV. fig. 11.)

The primary radial spines stout, styliform, nearly equidistant from each other, about as long as the radius of the shell; surface with numerous minute secondary spines. Diameter of cortical test  $\cdot 15$ , of medullary test  $\cdot 065$ ; length of primary spines  $\cdot 08$ , thickness at base  $\cdot 016$ ; length of secondary spines  $\cdot 01$  to  $\cdot 035$  millim.

*Distribution.* Abington, Lanarkshire.



Detached spicules of Radiolaria.—*a-f.* Three- and four-rayed spicules of *Sphaerozoum priscum*, sp. n. *g, h.* *Sphaerozoum patulum*, sp. n.: *g*, geminate, *h*, cruciform spicule. *i, k, l*, spicules of Plectoid Radiolaria. All enlarged to the scale of 200 diameters.

## Order COLLODARIA, Hæckel.

## Suborder B E L O I D E A, Hæckel.

Spumellaria with an imperfect skeleton composed of numerous solid needles or spicula, scattered irregularly in the calymma. (Chall. Rep. pt. i. p. 28.)

## Genus SPILÆROZOOM, Meyen.

Beloidea socialia or "Sphærozoida with branched or radiate spicula of one kind." (Chall. Rep. pt. i. p. 38.)

*Sphærozoom priscum*, sp. n. (Woodcut, a-f.)

Under this name I propose to include spicules of various dimensions, mostly with four rays, more rarely with only three. The rays are usually straight, simple, apparently conical, gradually tapering from a common centre to a point. Three of the rays are either in a plane or form a low tripod, and the fourth ray is nearly vertical to the others. There is a close resemblance in form, and approximately in size, of these detached spicules to the spicules of recent species of this genus and of allied genera of the same group, as shown in the 'Challenger' Report, pls. ii. and iv. The spicules are very abundant, for the most part indiscriminately mingled with one another and with the ordinary spherical shells; sometimes several are now situated close together, as if resulting from the disintegration in position of individual Radiolaria. It is very probable that these spicules may represent more than one species, and they are grouped under one name simply for convenience of reference. In form they are very similar to the spicules of Calcisponges; but there is not the least ground for suspecting that they may have belonged to these organisms, since their condition of preservation is the same as that of the undoubted Radiolarian shells amongst which they occur, and they are associated with other spicules which as regards form have no counterparts amongst sponge-spicules.

Detached Radiolarian spicules, both three-rayed and other forms, have already been described by Dr. Rüst\* from the Jurassic Strata of Western Switzerland and from the Neocomian of Gardenazza, and they are stated to be abundant in all Jurassic Radiolarian-bearing rocks.

The rays of the spicules range from .04 to .14 millim. in length and from .005 to .015 millim. in thickness.

\* 'Palæontographica,' Bd. xxxi. p. 284, pl. xxxi., Bd. xxxiv. p. 190.

*Distribution.* Abington, Lanarkshire; Broughton, Hartree Hill, Kilbucko, Peeblesshire; Moorfoots, Edinburghshire.

*Sphaerozoum patulum*, sp. n.  
(Pl. IV. fig. 12; woodcut, *g*, *h*.)

The spicules included under this term are geminate and cruciform. In the geminate forms there is a short central rod, from both ends of which two simple, subcylindrical, divergent rays are given off, approximately in the same plane (Pl. IV. fig. 12; woodcut, *g*). The rays are similar in the cruciform spicules, but the median rod is reduced to a slight central expansion (woodcut, *h*). Both kinds of spicules are present in recent species of the genus \*, and they have been likewise noted from Jurassic strata. The geminate spicules differ from any known kind of sponge-spicules.

The central rod of these spicules is from  $\cdot 015$  to  $\cdot 03$  millim. in length, and the rays are from  $\cdot 03$  to  $\cdot 13$  millim. in length.

*Distribution.* Broughton, Hartree Hill, Peeblesshire.

Subclass **NASSELLARIA**, Ehrenberg.

Order **PLECTELLARIA**, Hæckel.

Suborder **PLECTOIDEA**, Hæckel.

Nassellaria with a rudimentary, originally tripodal, skeleton, composed of radial spines arising from one common central point or central rod. (Chall. Rep. pt. ii. p. 898.)

There are a few forms in the chert which appear to belong to the above suborder, but they cannot be included in any of the known genera referred thereto by Hæckel; and it seems undesirable, since the specimens are rare and not perfect, to propose three new genera for them. In one specimen (woodcut, *i*) there are five straight, nearly cylindrical rays proceeding from a minute rounded centre; three of the rays are in one plane and one above and the other below this plane. On two of the rays are small spines or processes. The rays, when entire, are  $\cdot 15$  millim. in length. In another specimen (woodcut, *k*) there are five basal rays, with a stout ray rising from the centre. The rays are spinous, and there are traces of irregular tissue connecting them, as in the recent Plectanida (Chall. Rep. pt. ii. p. 919, pl. xcvi.). In the third specimen (woodcut, *l*), which is of unusual size, there are four basal rays radiating from a centre, from which also an upright ray springs. The rays are cylindrical and smooth and bifurcate,

\* 'Challenger' Report, pt. i. pp. 40-45, pl. iv.

the secondary rays tapering to an acute point. The entire length of one of the rays is .37 millim. I have only seen a single imperfect specimen of this form in the chert from Hartree Hill.

## EXPLANATION OF THE PLATES.

## PLATE III.

- Fig. 1. *Styptosphaera antiqua*, sp. n.  
 Fig. 2. *Spongoplegma priscum*, sp. n. The inner medullary sphere is shown by the dark central portion.  
 Fig. 3. *Dorysphaera reticulata*, sp. n. The radial spine in this specimen has been partially dislocated, and some of the mesh-apertures are infilled with the dark staining material.  
 Fig. 4. *Dorysphaera laxa*, sp. n. In this specimen the radial spine is viewed obliquely.  
 Fig. 5. *Dorysphaera nucula*, sp. n.  
 Fig. 6. *Stauroplegma barbatum*, sp. n. The medullary sphere in this specimen is indicated by the partially clear central space.  
 Fig. 7. *Dorydictyum simplex*, sp. n.  
 Fig. 8. *Doryplegma gracile*, sp. n.  
 Fig. 9. *Doryplegma nasutum*, sp. n. The lower portion of this specimen has been displaced by a quartz-vein. The inner or medullary sphere is indicated by the darker central area.  
 Fig. 10. *Diploplegma cinctum*, sp. n.  
 Fig. 11. *Haliomma vctustum*, sp. n. The mesh-apertures in the specimen are indistinct, owing to the dark infilling.

## PLATE IV.

- Fig. 1. *Acanthosphaera antiqua*, sp. n. The specimen is imperfect, a portion to the right having been cut off by a quartz-vein.  
 Fig. 2. *Triposphæra hastata*, sp. n. In this specimen only one of the three radial spines is preserved entire, the bases only of the other two remain. The inner sphere is partially clear and has not been infilled with the opaque material like the outer sphere.  
 Fig. 3. *Dorysphaera reticulata*, sp. n.  
 Fig. 4. *Stauroplegma diffusum*, sp. n. A quartz-vein traverses the right-hand portion of the specimen.  
 Fig. 5. *Stauroplegma brevispina*, sp. n. The upper portion has been displaced by a quartz-vein.  
 Fig. 6. *Stauroplegma compressum*, sp. n.  
 Fig. 7. *Staurodoras gracilis*, sp. n. Only the base of the lower spine remains. A quartz-vein traverses the specimen.  
 Fig. 8. *Haliomma cornutum*, sp. n.  
 Fig. 9. *Triposphæra Peachii*, sp. n.  
 Fig. 10. *Triposphæra densa*, sp. n.  
 Fig. 11. *Triposphæra armata*, sp. n.  
 Fig. 12. *Sphærozoum patulum*, sp. n. A geminate spicule, the rays imperfect, referred to this species.

The figures have been drawn by transmitted light from microscopic sections of the chert-rock in which the Radiolaria are imbedded; they are all enlarged to the same scale of 200 diameters. The specimens are all from the same zone in the Ordovician or Lower Silurian strata of the Southern Uplands of Scotland; the particular localities are given in the text.